

M E T R I C U N I T S

in Forestry:

What do they mean?

by G.M. Bonnor and K. Nietmann



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Metric Units in Forestry: What Do They Mean?

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Cette publication est aussi disponible en français sous le titre
Les unités métriques en foresterie : comment s'y retrouver.

Linear Measures

The use of metric units has been legal in Canada since 1871. Metric Commission Canada was set up 100 years later to initiate conversion to the International System of Units (Système international d'unités), abbreviated SI. Now, Canada is largely converted to this system of measurement.

Many Canadians find it difficult to think in terms of metric units. This is true in forestry, as well as other fields.

Most foresters do not know whether a growth rate of 25 m³/(ha.a) represents exceptional or poor growth for a particular species. This publication provides comparative values for the metric units used in forestry. It should give foresters a feeling for the magnitude of metric dimensions.

The SI units and their forestry applications are given first, average values and ranges for Canada are presented next, followed by values to be expected in other parts of the world. Values given are for mature trees or stands unless otherwise stated.

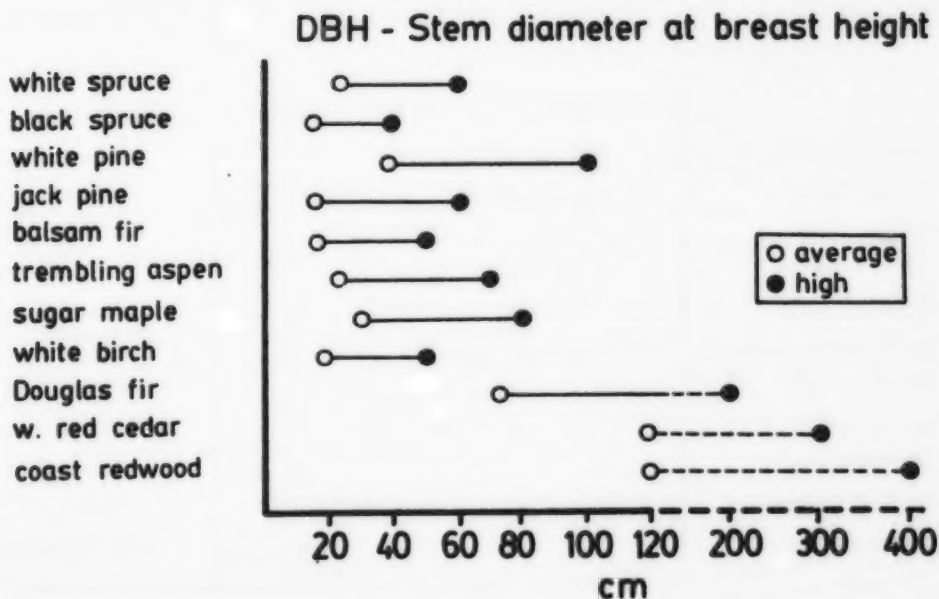
The linear SI units used in forestry are the centimetre (cm), which is used to measure tree diameters; the metre (m), which is used to measure tree heights as well as distances; and the kilometre (km), which is used to measure distances. One metre is equivalent to 100 cm, and 1000 m are equivalent to 1 km.

Tree Diameter

Tree diameter at "breast height" (dbh) is measured at 1.3 m above ground level. It is useful as a measure of tree size and in deriving other characteristics such as tree volume, basal area, and biomass.

Forty centimeters is an average diameter of the eastern white pine (*Pinus strobus*), although it can grow to 150 cm. Many trees have much smaller diameters. For example, black spruce (*Picea mariana*) averages 18 cm, while jack pine (*Pinus banksiana*) and trembling aspen (*Populus tremuloides*) average 22–24 cm. On the other hand, Douglas-fir (*Pseudotsuga menziesii*) in British Columbia easily grows to a diameter of 200 cm, as do other west coast species.

Habitat and site quality influence tree dimensions considerably. For instance, lodgepole pine (*Pinus contorta*) in British Columbia will average only 40 cm



in diameter at breast height on the coast, but will reach 60 cm in the interior of the province.

A diameter of 10 m (1000 cm), the largest in the world, has been attained by the coast redwood (*Sequoia sempervirens*) in the western United States.

Tree diameter may also be used to classify trees by merchantability. If a tree has a dbh less than a specified value (generally, 8–10 cm), it is considered non-merchantable. Similarly, tops of merchantable trees may be considered nonmerchantable.

Height

Tree height is useful as a measure of tree size but is more frequently associated with determination of stand height, tree volume, and site index. It varies, like diameter, with habitat. For example, lodgepole pine from the coast of British Columbia grows to between 10 and 15 m in height, while the same species growing inland reaches 30 m. The majority of hardwoods in Canada are about 20 m tall, but the sugar maple (*Acer saccharum*) and the silver maple (*Acer saccharinum*) average 25 m and may reach up to 40 m. Douglas-fir and Sitka spruce (*Picea sitchensis*) are the two tallest species in Canada, reaching heights of 90 m and 85 m, respectively. Western red cedar (*Thuja plicata*) is the next closest at 60 m. The tree that attains the greatest height is the coast redwood, with a height of 110 m, although at 100 m the giant sequoia (*Sequoiadendron giganteum*) comes a close second.

Distance

The units used in distance measurement are the metre (m) and the kilometre (km). Whether the metre or the kilometre is used depends on the distance to be measured. Distance in timber cruising, whether in establishing plots or in sampling points along a line, is usually measured using a tape or chain 30 or 50 m long. Distances are sometimes paced; the average pace (step) is about 0.75 m long. In mapping, distance may be expressed in metres or kilometres, depending on the map scale used. For example, a map scale of 1:1 000 000 means that 1 cm as measured on the map represents 1 000 000 cm or 10 km on the ground.

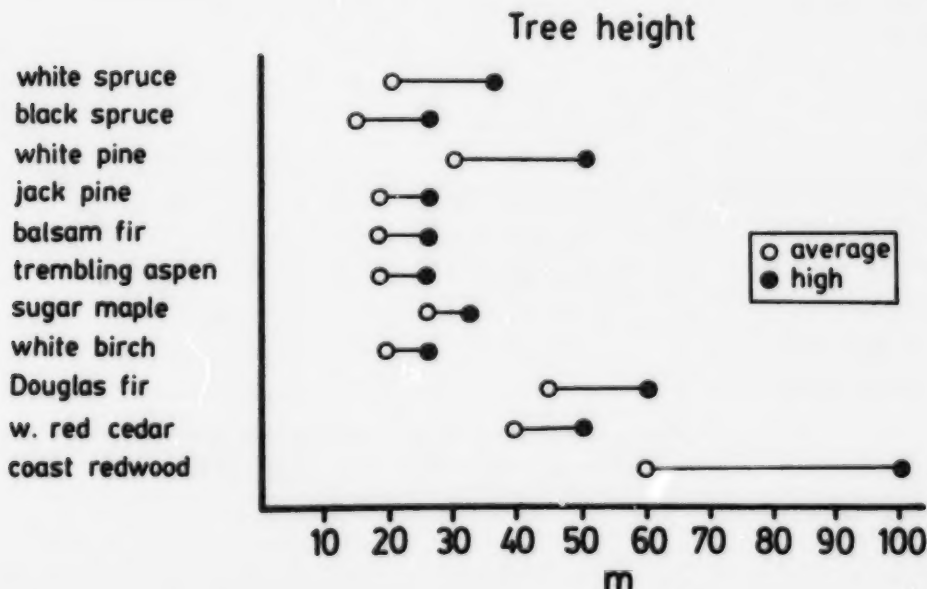
Area Measures

The areas measured in forestry are land area and basal area. Basal area and basal area growth apply to both trees and stands.

Land area

The SI units of area used in forestry are square metres (m²), hectares (ha), and square kilometres (km²). One hectare is equivalent to 10 000 m², and 100 ha are equivalent to 1 km². These units are used in measuring land area covered by forest stands and sample plots.

A Canadian football field is about two-thirds of a hectare in size. A quarter section comprises 64 ha.



Forest stands are most often measured in hectares. They range from a few hectares in size up to several hundred. Fifty hectares is the average size of a stand in central Ontario.

Basal area

The basal area of a tree is the cross sectional area of the stem measured at breast height. It is used in forestry to determine stand basal area (the sum of tree basal areas), which is closely related to stand volume.

The SI units used in forestry to measure tree and stand basal area are square metres (m^2) and square metres per hectare (m^2/ha). For individual trees, dbh is measured (in cm) and converted to basal area (in m^2). Stand basal area is obtained from sample plot measurements (see Sample Plots).

The basal area of a stand is a good measure of stand density and is useful in regulating thinning operations. The present basal area and the desired basal area are used to determine the size and number of trees to be cut.

Stand basal area shows considerable variation with species and geographic region. In Alberta, trembling aspen stands often range from 15 to 50 m^2/ha . Thirty to 70 m^2/ha is the range of balsam fir

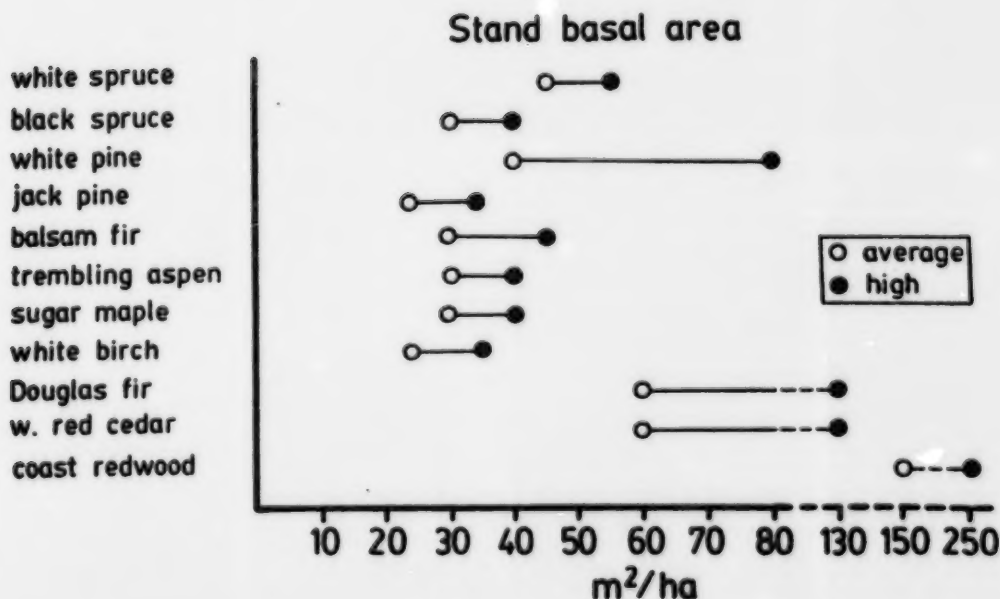
(*Abies balsamea*) in New Brunswick. In British Columbia, lodgepole pine stands typically have basal areas of 50 m^2/ha , although extremes of 100 m^2/ha exist.

The California coast redwood is one of the largest trees in the world. At ages of up to 1000 years, this species has attained a record 338 m^2/ha basal area. The basal area of mature stands, 400 to 800 years old, of this species can exceed 250 m^2/ha .

Basal area growth

This characteristic is of interest in growth studies and thinning practices. It is expressed in square metres per hectare per year ($m^2/(ha.a)$) and can be mean annual increment (MAI), current annual increment (CAI), or periodic annual increment (PAI). Of these, the MAI is most commonly used.

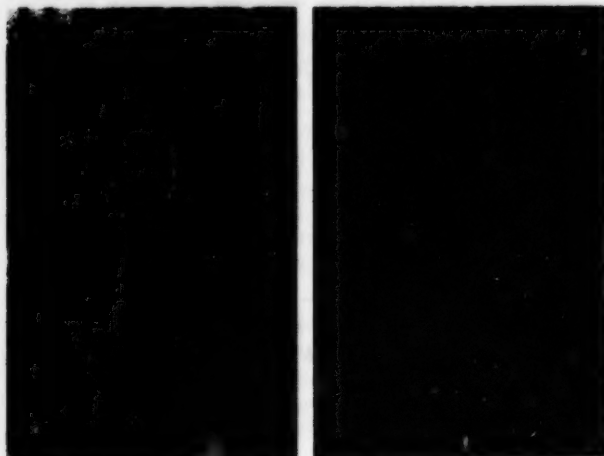
In Ontario, white spruce (*Picea glauca*) plantations have shown CAI values from 1.2 to 2.2 $m^2/(ha.a)$, depending on site quality. Trembling aspen in Alberta has shown MAI values ranging from 0.2 to 0.6 $m^2/(ha.a)$, depending on site quality.



Stereoscopic Photos and Metric Statistics of Selected Stands

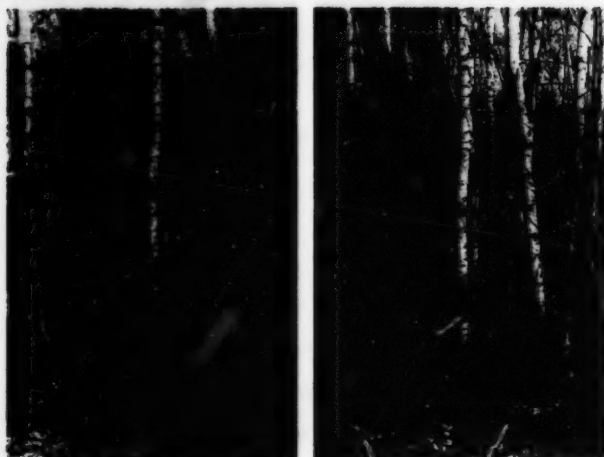
The stereo pairs can be viewed with a standard pocket stereoscope. The stand data were obtained from sample plot measurements. All trees with a dbh of 2.0 cm or more were measured. Merchantable

volume was calculated for trees with a dbh of 8.0 cm or greater, from a stump height of 30 cm to a top diameter inside bark of 8.0 cm. Biomass includes all above-ground tree components.



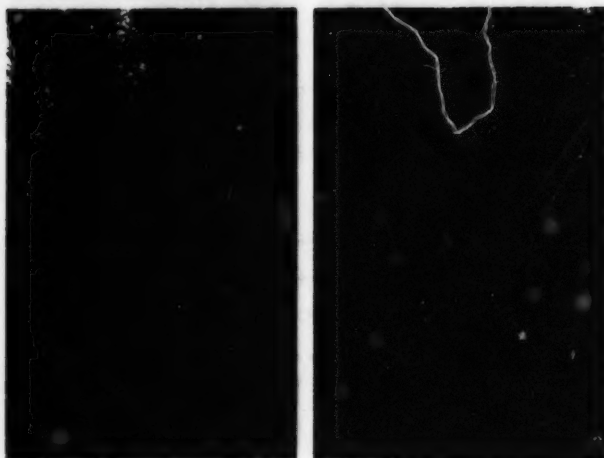
Pine-Hardwoods

Average Stand Diameter:	10 cm
Average Stand Height	: 18 m
Stem Frequency	: 1 000 trees/ha
Basal Area	: 15 m ² /ha
Volume (merchantable)	: 130 m ³ /ha
Biomass	: 75 t/ha



Mature White Birch

Average Stand Diameter:	20 cm
Average Stand Height	: 17 m
Stem Frequency	: 900 trees/ha
Basal Area	: 35 m ² /ha
Volume (merchantable)	: 200 m ³ /ha
Biomass	: 175 t/ha



Mature Tolerant Hardwoods

Average Stand Diameter:	25 cm
Average Stand Height	: 20 m
Stem Frequency	: 500 trees/ha
Basal Area	: 30 m ² /ha
Volume (merchantable)	: 200 m ³ /ha
Biomass	: 150 t/ha



Young Aspen

Average Stand Diameter: 6 cm
 Average Stand Height : 12 m
 Stem Frequency : 6 000 trees/ha
 Basal Area : 20 m²/ha
 Volume (merchantable) : 60 m³/ha
 Biomass : 50 t/ha



Mature White Pine

Average Stand Diameter: 36 cm
 Average Stand Height : 28 m
 Stem Frequency : 600 trees/ha
 Basal Area : 75 m²/ha
 Volume (merchantable) : 800 m³/ha
 Biomass : 375 t/ha



Mature Jack Pine

Average Stand Diameter: 19 cm
 Average Stand Height : 23 m
 Stem Frequency : 1 200 trees/ha
 Basal Area : 35 m²/ha
 Volume (merchantable) : 220 m³/ha
 Biomass : 125 t/ha

Sample Plots

Sample plots (fixed area) are measured in hectares or in square metres. Plot sizes vary from 4 m² to 1000 m² (0.1 ha), depending on the type of inventory and on the density and size of the trees. Smaller plots are used in dense stands of small trees, and larger ones in stands of widely spaced large diameter timber. In Canada, the 4-m² plot is often used in regeneration surveys, whereas plots of 400 to 800 m² (0.04–0.08 ha) generally are used in management inventories. A 40-m² plot used in a sapling inventory in the United States, and a 1000-m² (0.1 ha) plot used in the Finnish national forest survey, are examples of plot sizes used in other countries.

Sample plots of variable size are called point samples. In point sampling, a circular sweep is made with an angle gauge to select trees. The number of trees selected or included in the sample ("plot size") is a function of the angle subtended by the angle gauge (the Basal Area Factor, or BAF), of the size of the trees, and of their distance to the point of measurement. The BAF is the number of units of basal area per hectare represented by each selected tree, in m²/ha. For example, if an angle gauge has a BAF = 2 m²/ha (the most common factor in Canada), each selected tree represents a basal area of 2 m²/ha; if 12 trees are selected, the basal area at that point is 24 m²/ha. By measuring the dbh (and height) of the selected trees, other stand characteristics (stem frequency, volume) can be calculated.

Angle gauges with BAF = 1–5 m²/ha are commonly used, depending on the size of the trees in a stand: the larger the trees, the larger the BAF.

The thumb held at arms length can also be used as a crude angle gauge. Its BAF varies from about

3–6 m²/ha depending on the width of the thumb and length of the arm. (The BAF can be found using the formula $BAF = 2500 (w/L)^2$, where w is the width of the thumb and L is the distance from the thumb to the eye).

Volume Measures

Volumes of trees or stands are given in cubic metres (m³) or cubic metres per hectare (m³/ha). The units for measuring volume growth are cubic metres per year (m³/a) for individual trees, and cubic metres per hectare per year (m³/(ha.a)) for stands. Unless otherwise stated, the figures apply to gross merchantable volumes.

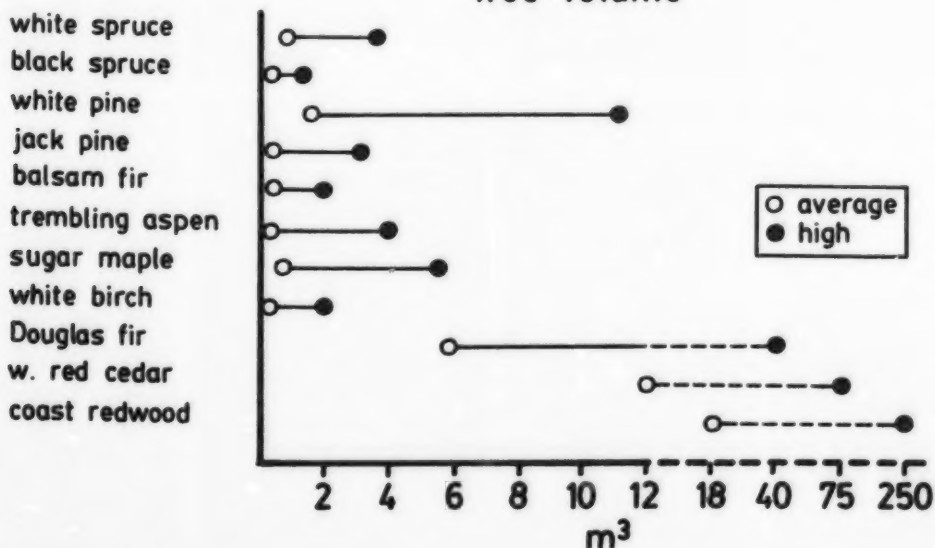
Tree volume

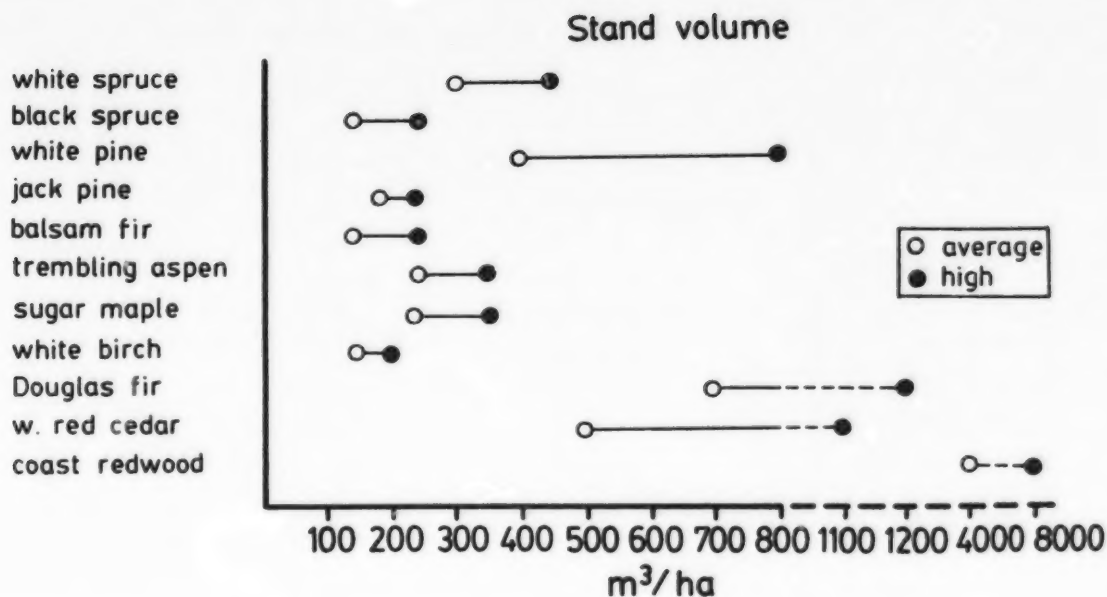
Tree volume is measured in cubic metres. It is a good measure of tree size but important primarily in the derivation of stand volume.

Across Canada, the following values are found:

- jack pine volumes range from 0.2–0.6 m³ but may go as high as 3 m³ under favorable conditions;
- white spruce has an average volume of about 0.5 m³ at maturity, reaching up to 6 m³ in good soil;
- trembling aspen volumes go from 0.2–0.4 m³, and may reach 4 m³ on good sites;
- red pine (*Pinus resinosa*) volumes vary from 0.6–3 m³ but may go to 7 m³;
- mountain hemlock (*Tsuga mertensiana*) volumes average up to 4 m³;
- large western red cedar may contain nearly 100 m³.

Tree volume





Stand volume

Stand volume is the characteristic of greatest significance in forestry. It is used to quantify the forest estate, as a basis for allocating harvests and assessing losses, and for many of the management and planning purposes.

Representative values across Canada are:

- young Douglas-fir on Vancouver Island may measure 240 m³/ha;
- Sitka spruce in British Columbia varies from 200–1200 m³/ha depending on site quality;
- white spruce stands in Ontario can exceed 300 m³/ha;
- jack pine volumes in Manitoba vary, depending on site, from 120 to 260 m³/ha.

Some of the highest stand volumes in the world have been recorded in the United States; mixed Douglas-fir and white fir (*Abies concolor*) have attained 1700 m³/ha, while redwood stands — also on the west coast — may attain a volume of 10 000 m³/ha at 1000 years of age.

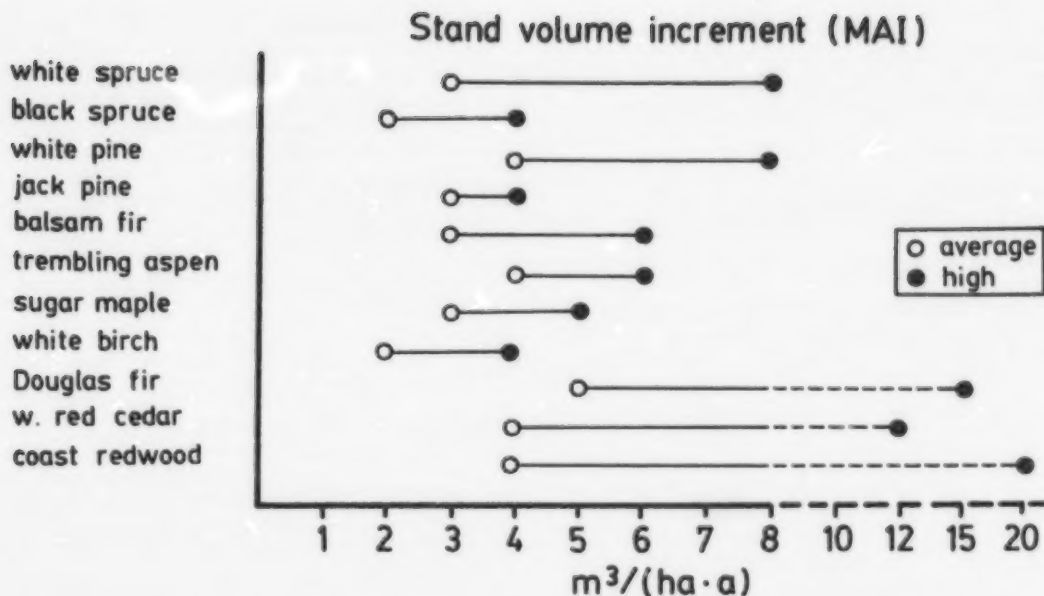
Stand volume growth

The metric unit used to measure volume growth is cubic metres per hectare per year (m³/(ha.a)).

The three measures of volume growth are — as for basal area — mean annual increment (MAI), periodic annual increment (PAI), and current annual increment (CAI). They are mainly applied to the volume growth of stands which in turn is used in growth projections, growth and yield studies, and modeling. The MAI is most commonly used.

In Saskatchewan, on good sites, black spruce has a mean annual increment of 2.5 m³/(ha.a). On medium quality sites, the MAI for this species is 1.6 m³/(ha.a) and on poor sites it can be as low as 0.1 m³/(ha.a). An MAI of 9.5 m³/(ha.a), and a PAI of 11 m³/(ha.a) can be found in red pine plantations in Ontario. The same species can have a PAI of 15 (m²/ha.a) on the best sites. Immature Douglas-fir stands in British Columbia have a PAI of 24 m³/(ha.a), and an MAI of 8.9 m³/(ha.a). Sitka spruce stands on good sites in B.C. have an MAI of 13 m³/(ha.a) at culmination age, while on very poor sites it can be as low as 1.5 m³/(ha.a).

Scots pine (*Pinus sylvestris*) in Great Britain has an MAI of 5–12 m³/(ha.a), depending on site. Thirteen to 16 m³/(ha.a) can be produced by mature coast redwoods from California. In Brazil, eucalyptus growing on a 7-year rotation can produce up to 83 m³/(ha.a).



Measures of Biomass

The SI units used in forestry to measure biomass are kilograms (kg), kilograms per hectare (kg/ha), tonnes (t), and tonnes per hectare (t/ha). One tonne is equivalent to 1000 kg. Generally speaking, the mass referred to is oven-dry in Canada, whereas in the United States it is green. Biomass is an attribute used in addition to, or in replacement of, volume. Whereas volume includes only the stem wood of each tree, biomass includes other tree components as well: stem bark, branches, foliage and, occasionally, roots. The components may be used for different purposes (sawlogs, pulpwood, energy); may have different energy content (wood vs. bark); and may or may not be removed and used, depending on the harvesting method.

Tree biomass

Tree biomass is measured in kilograms (kg). Typically, a mature conifer (25 cm dbh) will have an above-ground mass of about 200 kg, with another 30 kg contributed by the roots. A small conifer (10 cm dbh) will have an above-ground mass close to 15 kg. Most deciduous species of the same size will have a higher mass, by about 40 percent, due to their higher density. Component percentages do not vary much with tree size. Of the above-ground mass, about 70 percent is in the stem wood and 10–15 percent in each of the stem bark and branches, and 5 percent in the foliage. Although the stem wood percentage is

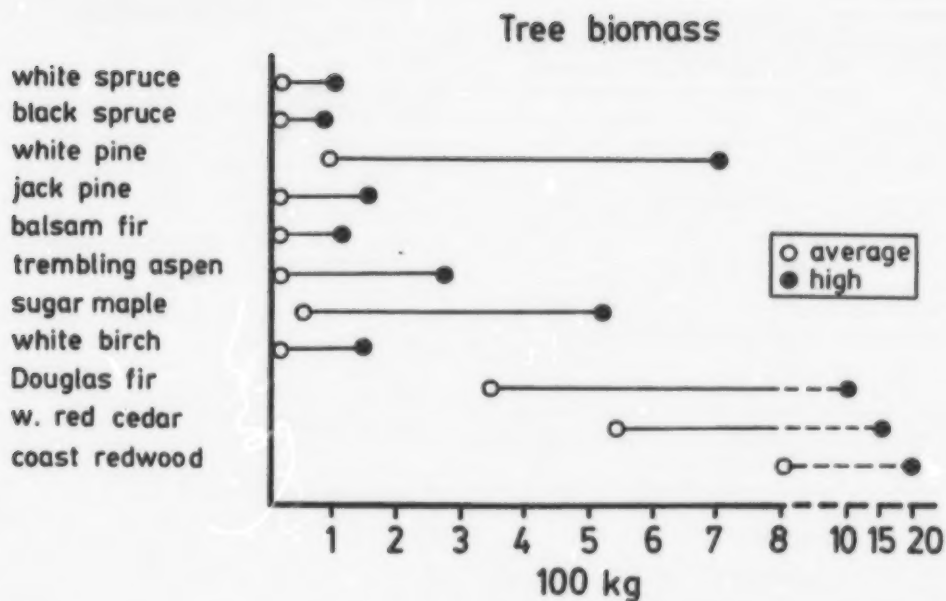
fairly constant, the percentage in the merchantable portion of the stem is not: as tree size decreases, so does the merchantable portion of the stem; small trees, generally less than 8–10 cm in dbh, have no merchantable stem.

In Alberta, large lodgepole pine will attain a biomass of up to 560 kg. The biomass recorded for an old amabilis fir in British Columbia is 1800 kg. A biomass of 15 000 kg can be found in large red cedars. Biomass values up to 25 000 kg can occur in coast redwoods in California.

Stand biomass

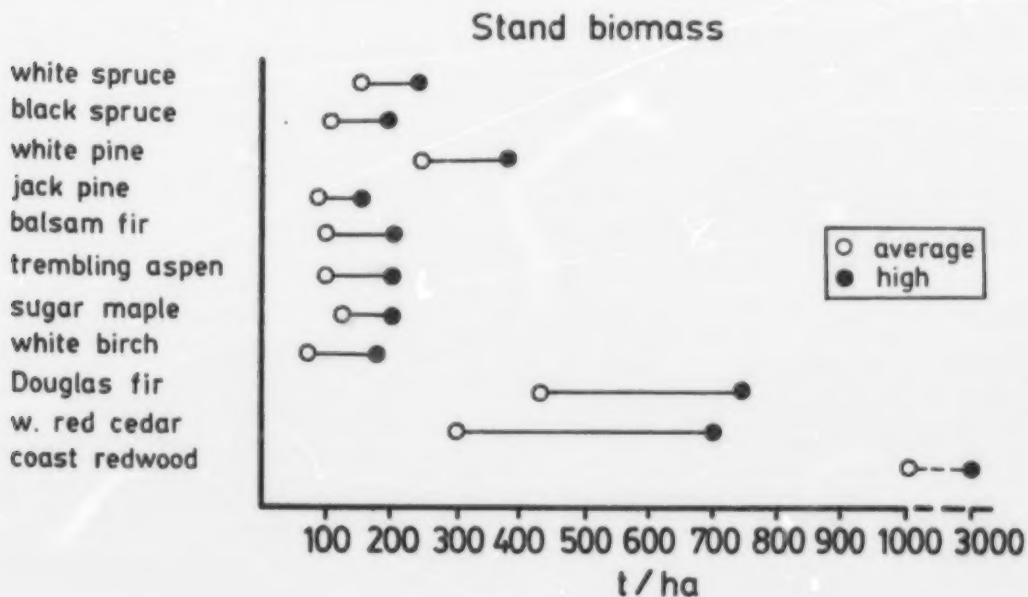
Stand biomass is measured in tonnes per hectare (t/ha), or tonnes (t). In Canada, provincial averages (of above-ground mass) range from 35–100 t/ha with the exception of British Columbia, which averages 158 t/ha. The territories average considerably less, at about 15 t/ha. The national average is 63 t/ha. This figure includes productive forests (90 t/ha) as well as unproductive forests (27 t/ha). For individual stands, the spread is much larger; whereas averages to 400 t/ha are not uncommon, some west coast forests exceed 1000 t/ha.

Stand biomass depends on stand age as well as on growing conditions. In young stands or regions of poor growth, the proportion of biomass in the small, nonmerchantable trees may be high, often exceeding 50 percent of total mass. Conversely, in the superior growing areas of British Columbia, the nonmerchantable portion of a stand is only a few percentage



points of the total. In such stands, the stem wood accounts for the major portion (up to 80 percent) of total biomass. For Canada as a whole, nonmerchantable trees contain about 20 percent of stand biomass, 50 percent merchantable stem wood, and the remaining 30 percent consists of bark, top, stump, branches, and foliage.

Some representative values are 100–150 t/ha for balsam fir stands in New Brunswick, 175 t/ha for hardwoods in Ontario, and 300 t/ha for amabilis fir stands in British Columbia. The highest measured values are for mature coastal redwoods in California, which have attained a biomass of 3300 t/ha.



Biomass growth

Only the growth of stands will be considered here because individual tree biomass growth is rarely used. The metric unit most commonly used is tonnes per hectare per year ($t/(ha.a)$). Current, periodic, and mean annual increment are measured, the last (MAI) most commonly.

Few statistics on forest biomass growth have been published. However, available figures indicate MAI values of 2–10 $t/(ha.a)$ for coniferous species in Canada. Also, the volume growth figures can be used as a guide: a range of 2–20 $m^3/(ha.a)$ translates into approximately 1.5–15 $t/(ha.a)$. In other countries, Douglas-fir stands in Belgium have produced 23 $t/(ha.a)$; Norway spruce in Japan and the USSR, 14 and 6 $t/(ha.a)$, respectively. The volume growth rate of 83 $m^3/(ha.a)$ for eucalyptus in Brazil converts into a biomass growth rate of 58 $t/(ha.a)$.

Summary

The use of SI units in Canada has come a long way since they were recognized as legal in 1871. However much they may be accepted and their use made mandatory, there is — and will be for some time — the problem of being able to understand, and attach a significance to, figures given in metric units. This publication has tried to bridge the gap in understanding what metric units mean in forestry.

Useful reading

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